Hot-wire visualization of the laminar boundary layer disturbances

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Abstract The spatial development of boundary layer disturbances was experimentally investigated using a hot-wire constant temperature anemometry. The method of introducing in flow of the controlled perturbations by round membrane is used to visualize the Blasius boundary layer disturbances at the flat plate. The pulse action of the round membrane lead to formation in the boundary layer of longitudinal localized streamwise structures and wave packets. The spatial development of wave packets is consistent with the linear theory of hydrodynamic stability.

Keywords: boundary layer, artificial localized disturbances, wave packets, wind tunnel experiments, laminar-turbulent transition

The boundary layer laminar-turbulent transition with an increased or moderate incoming flow turbulence level is associated with the development of disturbances generated by external turbulence. It is known [1-3] that the effect of incoming flow perturbations leads to the formation of longitudinally oriented localized structures (streaks) in the boundary layer consisting of areas with an excess and a deficit of longitudinal velocity. These structures provide the environments for the development of high-frequency wave disturbances, such as secondary instability and T-S wave packets evolving into turbulent spots under some favorable conditions. However according to recent studies [4-6] the effect of incoming flow perturbations can lead to the appearance of wave packets in addition to streaks.

The present investigations were carried out in the subsonic low-turbulent wind tunnels T-324 and MT-324 of ITAM SB RAS. Free stream velocity $U_\infty$ was 8, 20 and 21.5 m/s, free stream turbulence level Tu was 0.04 and 0.2 %$U_\infty$. The method of introducing in flow of the controlled perturbations is used. This method makes it possible detailed investigations of characteristics for artificially introduced perturbations with saving of phase information, to trace the dynamics of the development of a concrete disturbance at all its stages. Earlier the experimental investigations of the origin and development of disturbances, generated by impulse action of three-dimensional surface were conducted in the Blasius boundary layer and in the straight wing boundary layer [4]. It was found, that in all cases the elongated localized disturbances were generated. Such types of disturbances were classified as longitudinal localized streaky structures. With the presence of adverse pressure gradient flow a region of high-frequency wave packets appears and grows rapidly [5].

Present study is a continuation of research in the Blasius flow [6]. The behavior of longitudinal localized structures and wave packets in region of zero pressure gradient were experimentally studied in more detail. It is shown that high-amplitude impulse action of a three-dimensional (round) surface, located near the flate plate nose lead to formation of two types of disturbances in the boundary layer: longitudinal localized streamwise structures and wave packets, accompanying them. The law of the membrane motion looks like a long square pulse. The longitudinal structure arises due to a local deviation of the model surface (membrane) up or down. Its length along the flow is determined by the time during which the membrane is in a deflected position. Wave packets occur in a short period of time when the membrane makes its movement up or down, see figure 1. It was observed that the intensity of localized streamwise structure in downstream direction is decrease. What corresponds to the results of previous studies [2-6]. In the contrary, the wave packets amplitude is grow at the high Reynolds numbers. The spatial development of oscillations at the center frequency of wave packets is consistent with the linear theory of hydrodynamic stability.
Experiment show that wave packets consist of straight and oblique waves. The nature of their development is agreed with previous investigations on generation of wave packets by a point source [7].

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References


